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**Feriani et al.**

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(54) **SELF-SENSING RESPIRATORY TREATMENT DEVICE**

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(71) Applicant: **Henkel AG & Co. KGaA**, Duesseldorf (DE)

See application file for complete search history.

(72) Inventors: **Amir Feriani**, Auvornier (CH); **Cedric Zaugg**, Neuchatel (CH); **Jean-Paul Sandoz**, Cormondreche (CH); **Joseph Hess**, Bevaix (CH)

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(73) Assignee: **APTAR FRANCE SAS**, Le Neubourg (FR)

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(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 635 days.

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*Primary Examiner* — Theodore Stigell

(74) *Attorney, Agent, or Firm* — Griffin and Szipl PC

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(57) **ABSTRACT**

(51) **Int. Cl.**  
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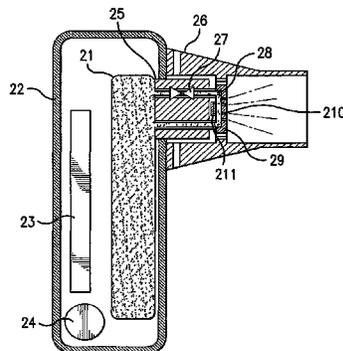
A respiratory treatment device comprising a self-sensing respiratory treatment device comprising: power supply means; a liquid dispensing element comprising an actuator and a dispensing aperture; electronic control means operable to control said actuator; liquid supply means; valving means; wherein said actuator is operable to execute in itself at least a dispensing function and a detecting function, the detecting function detecting at least characteristics external to the self-sensing respiratory treatment device and causing said actuator to generate a command signal, and wherein said electronic control means is operable to control said valving means and said actuator based on the reception of said command signal, wherein said actuator is a piezoelectric actuator, and the respiratory treatment device further comprising: a mouthpiece, and a fluidic interface, wherein said electronic control means and said piezoelectric actuator being arranged to detect a breathing pattern of a user through said mouthpiece.

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**5 Claims, 7 Drawing Sheets**

Breathing Pattern Detection



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*A61M 16/00* (2006.01)  
*B05B 1/30* (2006.01)  
*B05B 17/00* (2006.01)

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*B05B 17/0684* (2013.01); *A47K 5/1217*  
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 (2013.01); *A61L 2202/14* (2013.01); *A61L*  
*2209/11* (2013.01); *A61L 2209/111* (2013.01);  
*A61L 2209/132* (2013.01); *A61M 2016/0018*

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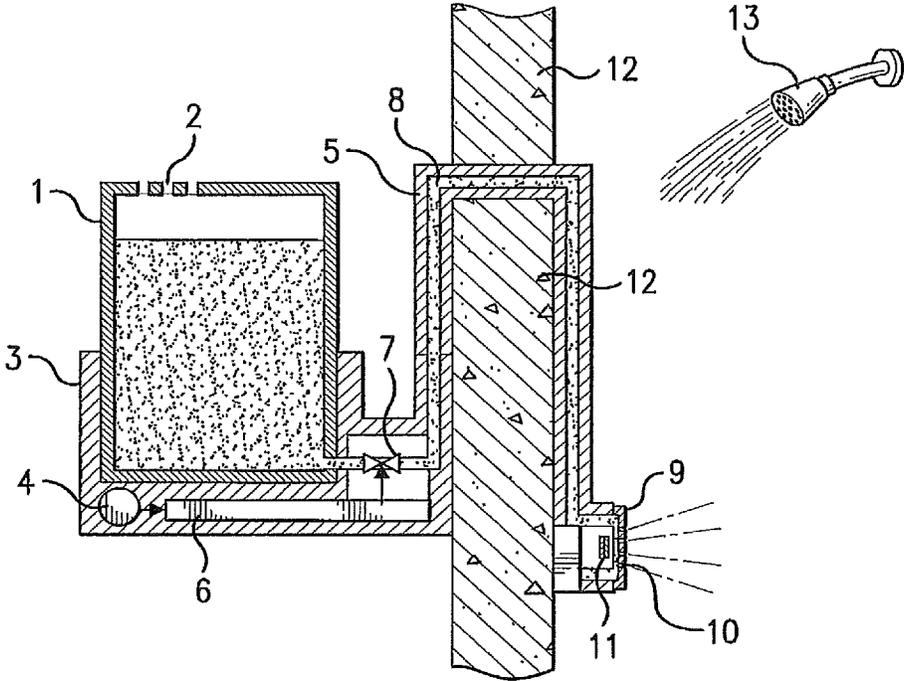


FIG.1a

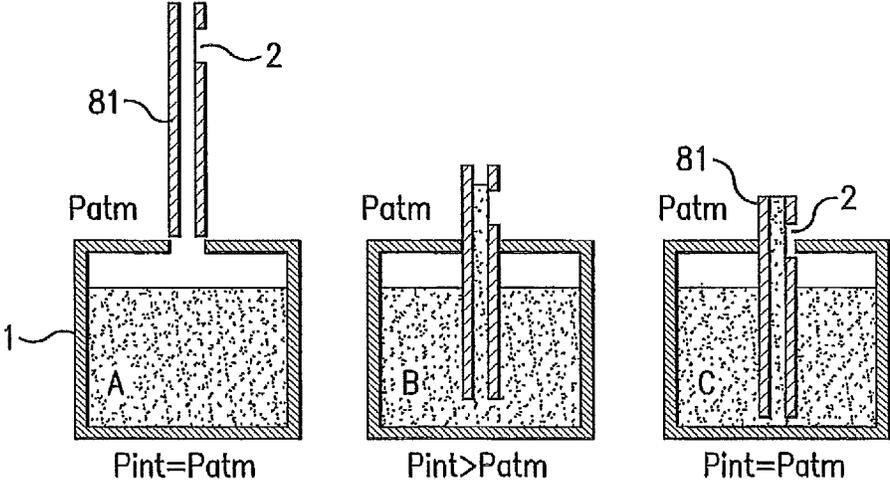


FIG.1b-1

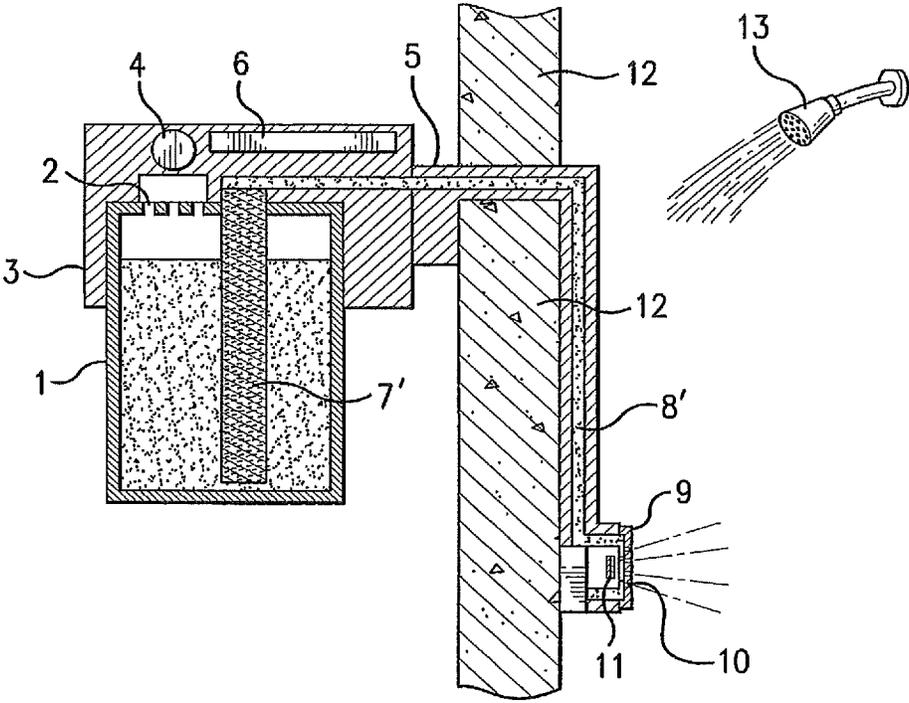


FIG.1c

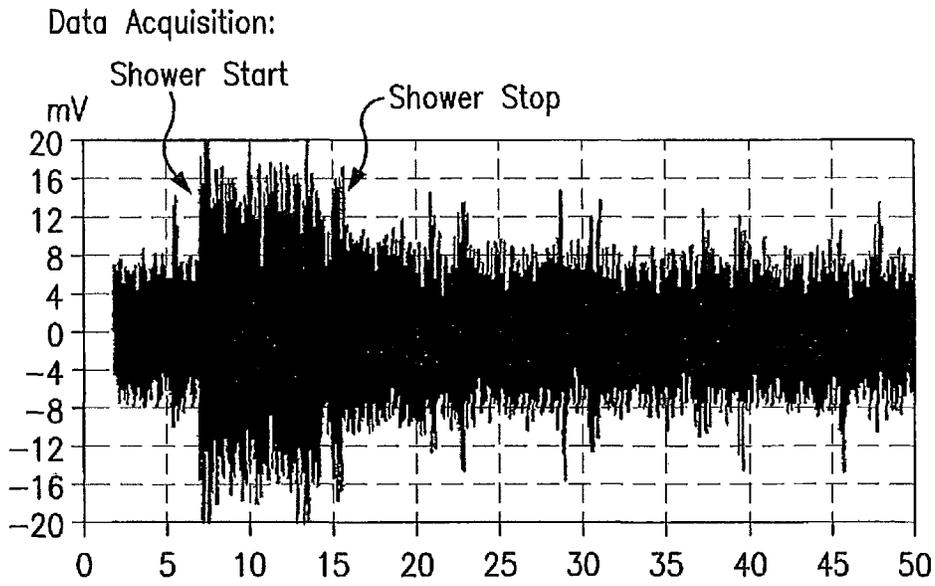


FIG.1d

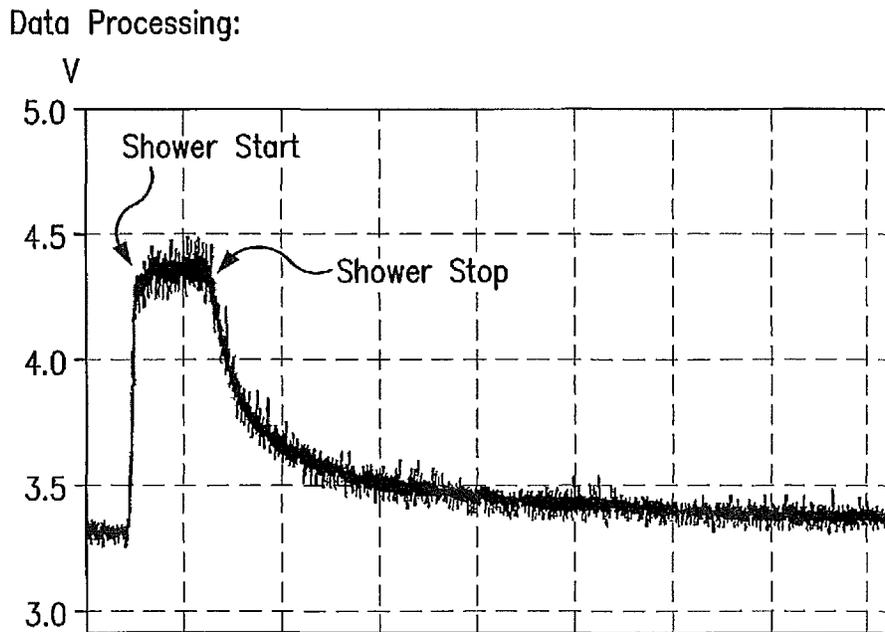


FIG.1e

Breathing Pattern Detection

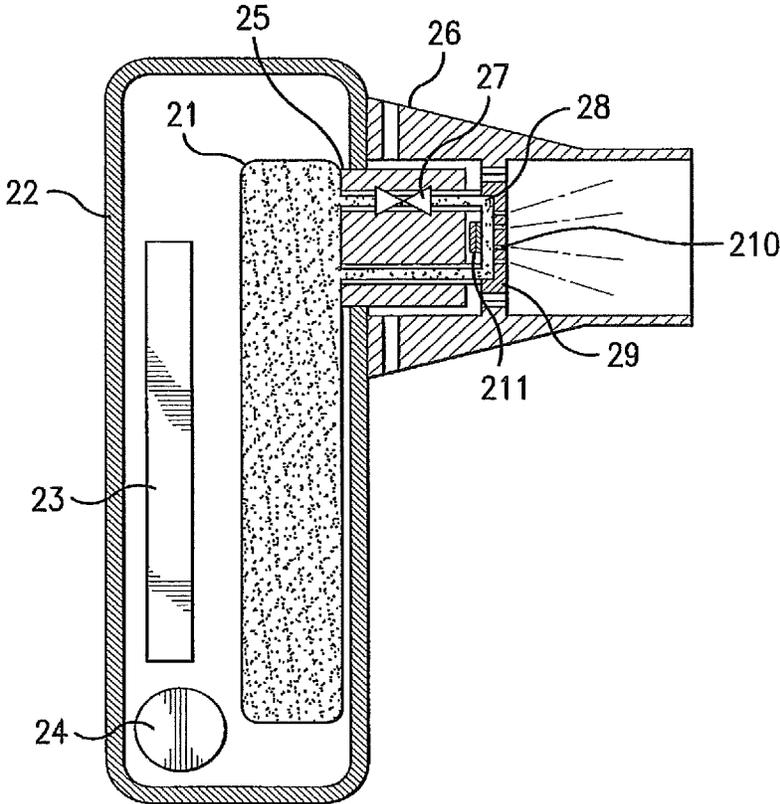


FIG.2a

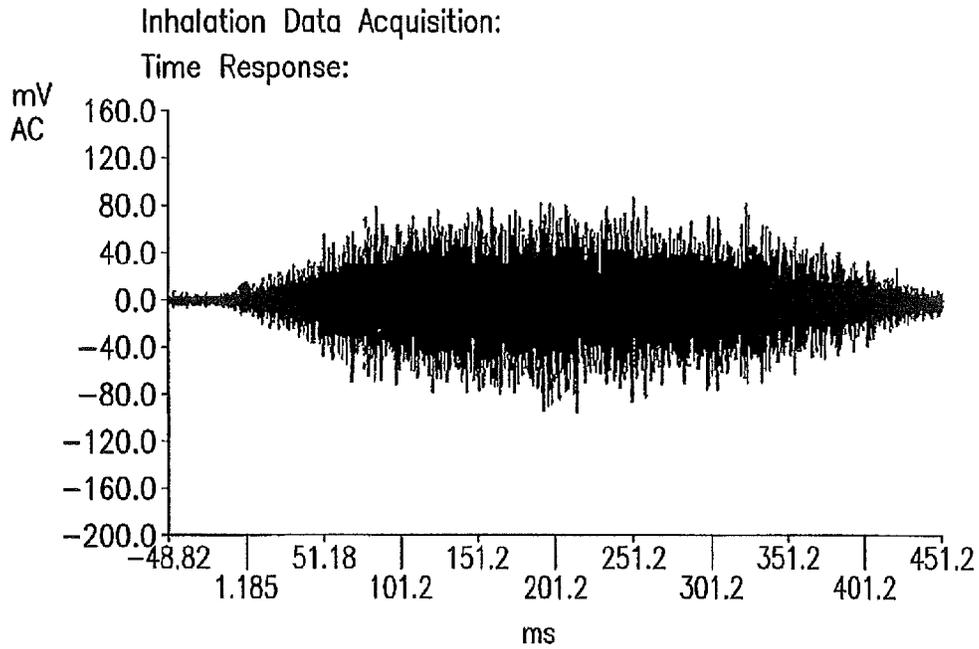


FIG.2b

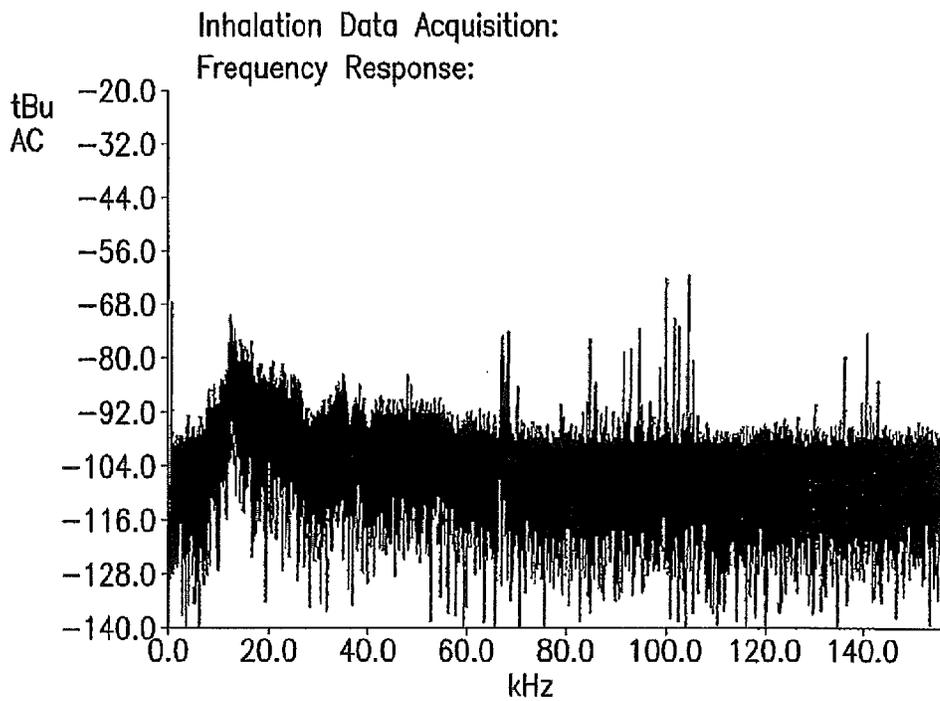


FIG.2c

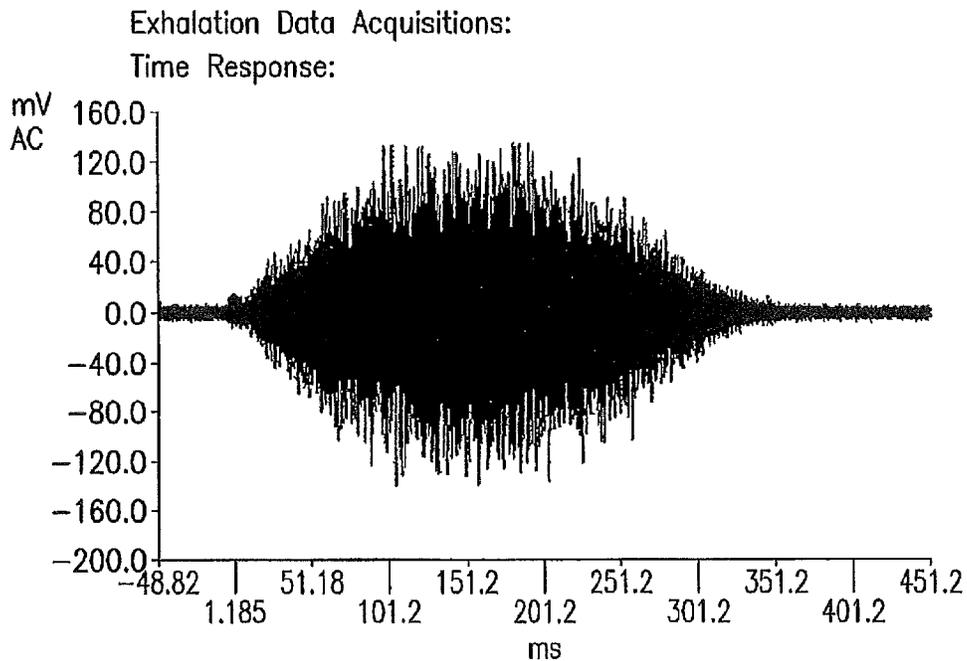


FIG.2d

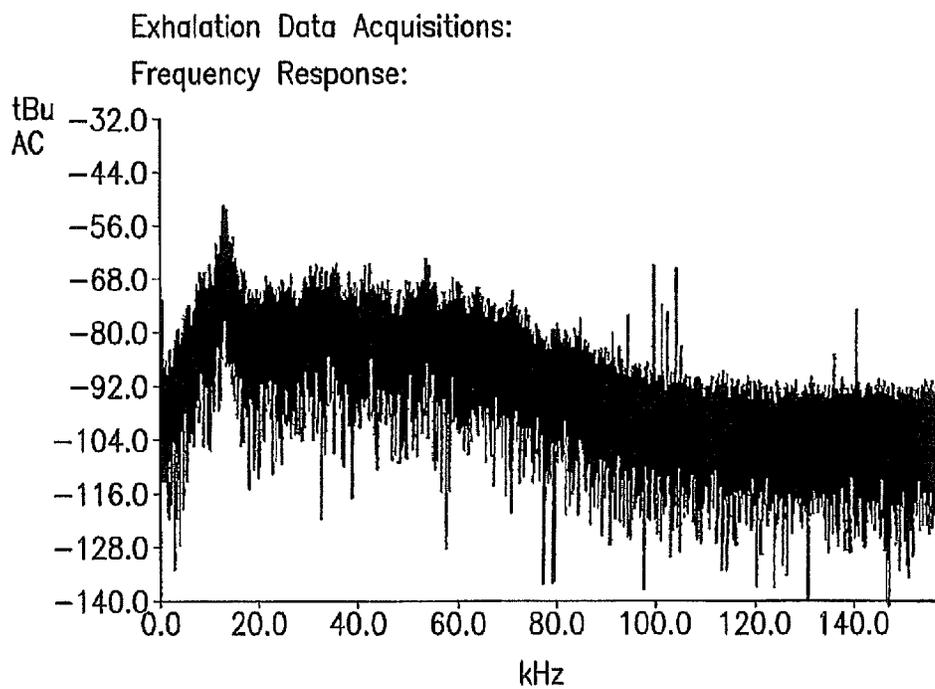


FIG.2e

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## SELF-SENSING RESPIRATORY TREATMENT DEVICE

### FIELD OF THE INVENTION

The present invention generally relates to a self-sensing respiratory treatment device, suitable for dispensing liquid substances, such as by activating a flow or a spray of droplets. Such device normally contains a dispensing body on a support part, in particular, a spout or a nozzle body of a liquid droplet spray device which dispenses a liquid substance from the device through the dispensing body. Such activation may be carried out by valving means to allow a flow and/or by pumping or pressurizing means. Such activation may further be carried out by a piezoelectric actuator used as a vibrating element for causing the liquid to vibrate so to be accelerated and expelled. A typical device further may consist of elements such as a liquid space, liquid feed and fluid interface to a reservoir, a reservoir as well as electrical connections between the vibrating element and a corresponding electronic circuitry. The liquid may be for example an ambient fragrance, a perfume, an insecticide, a fungicide, an aromatherapy essence, a liquid pharmaceutical formulation, a lotion, cream, emulsion, aqueous based liquids and flammable or combustible liquids.

### BACKGROUND OF THE INVENTION

Such dispensing bodies are sometimes called spouts, aperture plates, nozzle arrays, dosing apertures, orifice plates, vibratable membranes, atomizer, vibrating plate, dosing aperture arrangements, aerosol generators and the like. Such terms are hence to be understood as being interchangeable throughout the present document.

In fact such dispensing bodies and liquid dispensing devices are well known. For example see the document EP 1 129 741 in the name of the present Applicant. This document describes a dispensing device for spraying liquid and has a top substrate formed of a main body and of a nozzle body. The nozzle body contains a nozzle array of liquid droplet outlet means allowing a liquid substance contained in the liquid droplet spray device to exit the device, in this case as a spray of droplets. A piezoelectric actuator is used to cause the liquid to undergo a vibration so as to generate the droplet spray.

Generally, such piezoelectric actuator is driven so as to oscillate at or near an appropriate frequency to improve energy efficiency.

The document EP 1 043 162 describes an inkjet apparatus having a liquid detection method using an infrared detector to determine if liquid has passed through a spray path or not. Control means are provided to adjust the spraying itself.

The document US 2007/0216256 describes a drive control circuit for a piezoelectric activated pump. By measuring the internal impedance of the piezoelectric actuator, it is possible to control the operation frequency.

Document US2003/0146300 describes a nebulizer for nebulizing a substance and a reservoir having a metering chamber arranged so as to feed a substance to be nebulized from the nebulization device and a second chamber arranged to hold and retain any of this substance in excess of the volume held in the metering chamber. The device allows detecting the ejection of a unit dose.

However, a simplified and reliable controlled activation and deactivation of the actuator would be useful if the

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actuator could function by itself so as also to detect dispensing conditions and to control and/or monitor liquid dispense actuation.

It is, therefore, an object of the present invention to provide an innovative dispensing device that overcomes the inconveniences and limitations presented by the prior art documents.

Thus, the present invention concerns a respiratory device fulfilling these objectives efficiently which may be obtained in a relatively simple and inexpensive manner, as defined in the appended claims. The device is further capable of indirectly triggering and monitoring itself.

Furthermore, other desirable features and characteristics of the present invention will become apparent from the subsequent detailed description of the invention and the appended claims, taken in conjunction with the accompanying drawings and this background of the invention.

### BRIEF SUMMARY OF THE INVENTION

Respiratory treatment device comprising a self-sensing respiratory treatment device comprising: power supply means; a liquid dispensing element comprising an actuator and a dispensing aperture through which liquid is to be dispensed by activation of the actuator; electronic control means operable to control said actuator; liquid supply means for connecting with a liquid reservoir to supply liquid from said reservoir to said liquid dispensing element; valving means for allowing or blocking liquid to flow from said reservoir through said liquid supply means to said liquid dispensing element; wherein said actuator is operable to execute in itself at least a dispensing function and a detecting function, the detecting function detecting at least characteristics external to the self-sensing respiratory treatment device and causing said actuator to generate a command signal; and wherein said electronic control means is operable to control said valving means and said actuator based on the reception of said command signal, wherein said actuator is a piezoelectric actuator, and the Respiratory treatment device further comprising: a mouthpiece, and a fluidic interface, said electronic control means and said piezoelectric actuator being arranged to detect a breathing pattern of a user through said mouthpiece.

### BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will hereinafter be described in conjunction with the following drawing figures, wherein like numerals denote like elements, and

FIG. 1a shows an example of a self-sensing piezoelectric dispensing device not forming part of, but useful for understanding the present invention used in a water flow detector of a shower apparatus;

FIG. 1b1 shows an example of a priming system for a self-sensing piezoelectric dispensing device in example;

FIG. 1c shows an example of a self-sensing piezoelectric dispensing device in the first embodiment;

FIGS. 1d and 1e show examples of signals used in a water flow detection in the first embodiment;

FIG. 2a shows an example of a self-sensing piezoelectric dispensing device in the embodiment according to the present invention used in an inhaler or nebulizer;

FIGS. 2b and 2c show a time domain response and a frequency response for a detected inhalation airflow of a person using a self-sensing piezoelectric dispensing device in the embodiment; and

FIGS. 2*d* and 2*e* show in analogy the detected exhalation flow of the self-sensing piezoelectric dispensing device in the embodiment.

#### DETAILED DESCRIPTION OF THE INVENTION

The following detailed description of the invention is merely exemplary in nature and is not intended to limit the invention or the application and uses of the invention. Furthermore, there is no intention to be bound by any theory presented in the preceding background of the invention or the following detailed description of the invention.

Thanks to the features of the self-sensing respiratory treatment device according to the present invention, it is possible to reliably control the operation of the device, and this without requiring any separate sensor.

Other features and advantages of the self-sensing respiratory treatment device according to the present invention will become clear from reading the following description, which is given solely by way of a non-limitative example thereby referring to the attached drawings.

An example of a preferred embodiment will now be described while referring to the figures. Generally, the self-sensing respiratory treatment device according to the present invention is used to control the operation of an actuator in a liquid dispensing device.

A self-sensing piezoelectric dispensing device is used as a water flow detector arranged close to a showerhead of a shower apparatus. By detecting a flow of water, a cleaning, disinfecting or fragrancing formulation, or the like, may be dispensed from the self-sensing piezoelectric dispensing device. This may be done for example by way of a spray of droplets, i.e. in such a case the dispensing device is an atomizer or liquid droplet spray device.

Shower cleaning devices are known as such. For example, the document U.S. Pat. No. 6,820,821 discloses an automated sprayer for spraying the walls of a bath and shower enclosure with a cleanser. The sprayer has a housing that can be mounted inside the shower enclosure. A tube extends downwardly along a longitudinal axis through which the cleanser can pass. A motorized head disposed beneath the tube can be rotated about the axis for metering cleanser from the bottle and spraying cleanser outward. The sprayer includes a motion sensor to prevent spraying if someone is present in the shower.

Clearly such device requires a separate sensor to allow for triggering of the desired operation (spraying of cleaner) making the system more vulnerable and more expensive.

Thanks to these features, a separate sensor can be avoided, as it is the piezoelectric actuator itself that functions as a sensor. Therefore, reliability can be improved, as there are fewer parts prone to malfunctioning.

An example is shown in FIG. 1 where a pressurized cleaner tank 1 is provided for containing a liquid. A venting hole 2 is advantageously provided with a hydrophobic membrane to ensure correct priming by tank over-pressuring and also to ensure correct emptying of the tank.

Alternatively, as shown in FIG. 1*b*1, instead of a hydrophobic membrane, a liquid feed conduit 81 having a cut-out section acting as a venting hole 2 can be used to pressurize the liquid and to vent the tank and feed the liquid to an inlet channel 8. As shown in this Figure, first this liquid feed conduit 81 is ready to be inserted into the tank (A). At this stage, the pressure  $P_{int}$  in tank 1 is equal to the atmospheric pressure  $P_{atm}$ . Next, it enters the tank (B), so that the internal pressure  $P_{int}$  becomes greater than  $P_{atm}$ . Finally it arrives at

the bottom of the tank such that the venting hole allows for release of air (C) so that  $P_{int}$  equals again  $P_{atm}$ .

Tank 1 is placed in a housing 3 fitted to a shower apparatus having a showerhead 13. Housing 3 further contains a battery 4 and appropriate electronic control means 6 for activating and deactivating a dispensing element, here a liquid spray head 9. Liquid spray head 9 is mounted on a support, for example a wall 12 in the vicinity of showerhead 13. Liquid spray head 9 comprises a piezoelectric actuator 11 and an aperture plate or nozzle head 10 having one or more outlet nozzles through which the liquid cleaning solution is expelled as a spray of droplets, in a manner well known to a person of the art. An inlet channel 8 is provided to supply liquid from tank 1 to spray head 9. Inlet channel 8 may be mounted to support 12 by way of a clip 5. Access from tank 1 to spray head 9, through inlet channel 8, may be controlled by valving means, for example an electro-valve 7, suitably arranged between the tank and the spray head, and controlled by electronic control means 6.

As the person skilled in the art will readily recognize there can be one or more tanks and one or more liquids. Electro-valve 7 can be a one way or multi-way valve. There can be one or several liquid spray heads. Also the tank arrangement and the liquid spray arrangement may be side by side on a surface instead of on different sides of a wall such as shown in FIGS. 1*a*, and 1*c*.

As such, any liquid supplied to spray head 9 is put into vibration by piezoelectric actuator 11 so that ultrasonic energy thus created acts on liquid in spray head 9 to cause it to be ejected as a spray of droplets through the nozzle(s) 10, in a manner known to the skilled person.

Indeed, the piezoelectric actuator is operable to execute at least a dispensing function and a detecting function. The dispensing function may be triggered by an electronic control signal from electronic control means 6 for vibrating the piezoelectric actuator, whereby the ultrasonic energy is transmitted to the liquid so as to allow for vibration thereof, thereby resulting in the dispensing of the liquid from said dispensing element through the nozzle(s) 10. The detecting function is used to detect at least characteristics external to the dispensing device and results in a perturbation of the piezoelectric actuator. This perturbation generates an electronic signal, which may be detected by electronic control means 6, and thus may constitute a command signal of electronic control means 6 for controlling valving means 7 and spray head 9.

As can be understood from the above, piezoelectric actuator 11 not only allows liquid to be dispensed, but it also allows to control when, how and which liquid (when using more than one tank) is to be dispensed. In fact, by using the principle of piezoelectricity not only to convert electricity to mechanical movement, but also to convert mechanical perturbations back to electricity, the piezoelectric actuator 11 can be used to detect external characteristics, in this case water flow of the shower, as such water flow creates combined sonic and ultrasonic pressure waves in the proximity of the shower apparatus, which causes perturbation that can be picked up by piezoelectric actuator 11, thus allowing to detect the water flow. By appropriate analysis of the electrical signals resulting from the water flow pressure waves through electronics means 6, it is possible to determine when water flow starts and stops. It is then also possible to control, once the water flow is detected as started, electro-valve 7 so that liquid may be provided from tank 1 to spray head 9 and thus be ejected by self-sensing actuator 11. This control can be carried out by the electronic control means 6, triggered by the self-sensing piezoelectric actuator 11. Thus, a shower

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apparatus having such a water flow detector can then automatically trigger release of a cleaning, fragrancng or disinfecting substance.

The analysis of the electrical signals resulting from the water flow-generated pressure waves will be explained in more detail with respect to FIGS. 1*c* and 1*d*. As can be seen in FIG. 1*e*, the start and stop of the water flow can be readily detected as the pressure waves detected by piezoelectric actuator 11 increase sharply when water flow starts, and decrease rapidly when the water flow stops. Using this signal, it is possible to apply a threshold detection additional to the above analysis, as shown for example in FIG. 1*d*, above which a water flow is considered to be in progress. Thus, the start and stop of a water flow can be readily detected by the self-sensing spray head 9.

The piezo-generated electric signal undergoes appropriate filtering in order to reliably isolate the water flow-originated signal from everything else picked-up (i.e. background noise).

In the embodiment of the present invention, the self-sensing piezoelectric dispensing device is used as a breathing pattern detector in a respiratory treatment device allowing to trigger the release of a substance.

Respiratory treatment devices are generally known as inhalers or nebulizers for delivering active substances to a user by means of his or her respiratory system. It may be used e.g. for the controlled administration of drugs or for a variety of treatments including therapies and general wellness oriented applications. The respiratory treatment device delivers the substance which may be in the form of a liquid or gel as a dispersion of atomized droplets. Preferably, such a device is small in size and battery operated so that the user may carry and use it in a discreet manner. Such devices are well known as such, see for example the documents EP 923 957 or U.S. Pat. No. 6,4059,34B1 both in the name of the present Applicant.

FIG. 2*a* shows an example of a respiratory treatment device comprising a self-sensing piezoelectric spray head 29 according to the present invention. A reservoir 21 is provided attached to a housing 22. Reservoir 21 may contain a substance that is to be expelled as a spray of droplets from the inhaler into the mouth of a person operating the respiratory treatment device. The respiratory treatment device further comprises a mouthpiece 26 and a fluidic interface 25 allowing the substance from reservoir 21 to arrive at the mouthpiece 26. Mouthpiece 26 contains a liquid dispensing element, i.e. spray head 29, comprising a piezoelectric actuator 211 and a nozzle head 210 having one or more outlet nozzles through which the substance is expelled as a spray of droplets. This spray head may of course be similar to the one of the first embodiment. In a similar manner to the first embodiment, an inlet channel 28 and valving means, such as an electro-valve 27 may be provided for supplying the substance from reservoir 21 to spray head 29.

Housing 22 comprises electronic control means 23 and a power source such as battery 24 for supplying power to the electronic control means 23 and to the piezoelectric actuator 211. Again, these parts may be identical to those described in the first embodiment.

According to the second embodiment, piezoelectric actuator 211 again converts mechanical perturbations to electricity, but now applies the principle to the detection of the inhalation and exhalation pattern of a person using the respiratory treatment device. Indeed, when putting the mouthpiece into the mouth, a person will inhale and exhale. This inhalation/exhalation causes perturbations of the piezoelectric actuator, so that the inhalation and exhalation air-

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flows of the person can be detected. By appropriate analysis of these inhalation and exhalation sequences, the substance to be administered can be expelled as a spray by the self-sensing spray head 29 at the appropriate time to allow for an efficient treatment, i.e. while the person is actually inhaling, and not exhaling.

FIGS. 2*b* and 2*c* show the time response and the frequency response for a detected inhalation of a person. By using an appropriate time-frequency analysis, the beginning and the end of the inhalation process can be clearly detected. By using, for example, a threshold detection additional to the above analysis, the electronic control means 23 can trigger electro-valve 27 to allow substance to be supplied to spray head 29 for spraying into the person's mouth after detection of the beginning of the inhalation process and then electro-valve 27 can again be closed to block further access of substance to the spray head, once the end of the inhalation process is detected.

FIGS. 2*d* and 2*e* show in analogy the exhalation process detected by piezoelectric actuator 211. Thus, this process is carried out in an analogous manner to the one described above for the inhalation process. As such, triggering of the spray device may be prevented during exhalation.

By using these detection methods, the inhalation can be differentiated from the exhalation. Indeed, as can be seen from FIGS. 2*b* to 2*d*, the inhalation and exhalation can be differentiated by an appropriate time-frequency analysis.

As can be understood from the above, in this embodiment, again the release of a substance from reservoir 21, and thus from the dispensing device is controlled by signals provided by the self-sensing piezoelectric actuator 211.

Additional advantages of the self-sensing respiratory treatment device according to the present invention concern the fact that sensing and dispensing actions are carried out by the same component. In conventional devices, a dispensing device could continue to dispense even when the separate sensor has failed, thus leading to waste of the dispensed liquid. For an inhaler, this could even be dangerous to a patient, as the inhaled dose may be much higher than permitted.

Clearly, a cheaper device may also be obtained, as no separate sensor needs to be provided, connected and calibrated.

Further, respiratory treatment device according to the present invention may be provided with self-learning technology. For example, the electronic control means may be provided with a memory for storing detection results and to allow for a self-calibration, by comparing with previously stored detection results. For instance, the electronic control means may analyze the envelope of the command signal generated by the actuator by comparing it with pre-stored signals, the result of this comparison allowing to trigger the actuation means.

Moreover, the present self-sensing piezoelectric dispenser may even detect clogging, as this leads to modification of the electro-mechanical characteristic of the self-sensing piezoelectric dispenser.

Also, an empty detection in the dispenser can be performed in this manner, so the piezoelectric actuator can be stopped.

While at least one exemplary embodiment has been presented in the foregoing detailed description of the invention, it should be appreciated that a vast number of variations exist. It should also be appreciated that the exemplary embodiment or exemplary embodiments are only examples, and are not intended to limit the scope, applicability, or configuration of the invention in any way. Rather, the

foregoing detailed description will provide those skilled in the art with a convenient road map for implementing an exemplary embodiment of the invention, it being understood that various changes may be made in the function and arrangement of elements described in an exemplary embodiment without departing from the scope of the invention as set forth in the appended claims and their legal equivalents.

What is claimed is:

1. Respiratory treatment device comprising:

- a self-sensing respiratory treatment device comprising
  - power supply means,
  - a liquid dispensing element comprising an actuator and a dispensing aperture through which liquid is to be dispensed by activation of the actuator,
  - electronic control means operable to control said actuator,
  - liquid supply means for connecting with a liquid reservoir to supply liquid from said reservoir to said liquid dispensing element,
  - valving means for allowing or blocking liquid to flow from said reservoir through said liquid supply means to said liquid dispensing element,
- wherein said actuator is operable to execute in itself at least a dispensing function and a detecting function, the detecting function detecting at least characteristics external to the self-sensing respiratory treatment device and causing said actuator to generate a command signal, and

- wherein said electronic control means is operable to control said valving means and said actuator based on the reception of said command signal,
- wherein said actuator is a piezoelectric actuator, and the respiratory treatment device further comprises:
  - a mouthpiece, and
  - a fluidic interface, said detecting function of the piezoelectric actuator detecting an inhalation and exhalation pattern of a person using the respiratory treatment device through said mouthpiece, the inhalation/exhalation of the person causing perturbations of the actuator, so that the inhalation and exhalation airflows of the person can be detected.
- 2. The respiratory treatment device of claim 1, wherein said electronic control means is operable to open and/or close said valving means based on said command signal.
- 3. The respiratory treatment device of claim 2, wherein said electronic control means is operable to turn on and off said self-sensing respiratory treatment device based on said command signal.
- 4. The respiratory treatment device of claim 1, wherein said electronic control means is operable to analyze a time-frequency response of said command signal, the result of said analysis allowing to trigger said valving means.
- 5. The respiratory treatment device of claim 4, wherein said electronic control means comprises memory means for storing results of said analysis for self-learning purposes.

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